Pest Management Grants Final Report

INTEGRATED WEED MANAGEMENT FOR LETTUCE: OPTIMIZED WEED MANAGEMENT INPUTS MADE ACCORDING TO SEASONAL FLUCTUATIONS IN WEED SEED GERMINATION

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Abstract

Vegetables such as lettuce have very few herbicide tools compared to major crops such as field corn, therefore, optimal use of existing herbicides is prudent. Furthermore, current regulatory efforts such as the Food Quality Protection Act may result in the loss of one or more of the currently registered lettuce herbicides. To better understand common vegetable field weeds, and to identify improved management practices, we are investigating the germination characteristics of weeds in the Salinas Valley. Many weed species do not germinate consistently throughout the year, instead they have seasonal periods of high and low germination. We have monitored Salinas Valley vegetable field weed germination, and soil seedbanks for a 12 month period. Our results indicate that weeds such as shepherdspurse germinate most heavily during the fall and winter, while warm-season weeds such as common purslane germinate most heavily in July and August. Pronamide is active on most of the weeds that infest lettuce throughout the year. Pronamide is not very active on pigweed species, but bensulide is effective on pigweed. Therefore, bensulide may be a better choice for late-summer planted lettuce.

Executive summary

In the vegetable districts of the central coast of California lettuce is planted from December to September, and the dominant weed species during these long planting intervals varies by season. During cool months, winter annuals such as common chickweed (*Stellaria media*), pineappleweed (*Matricaria matricarioides*) and shepherdspurse (*Capsella bursa-pastoris*) predominate, while during the warm months summer annuals such as common purslane (*Portulaca oleracea*), hairy nightshade (*Solanum sarrachoides*) and pigweeds (*Amaranthus* spp.) predominate. Management of these weeds in vegetable crops is accomplished through a combination of herbicides, mechanical tillage and hand hoeing. Because herbicide options are increasingly more limited in vegetable crops, our principal research objective is to enhance the value of existing weed control inputs through greater understanding of weed germination characteristics. Soil samples from two vegetable fields were taken every 6 weeks during March 1998 to March 1999 to detect shifts in the seed dormancy status of several weed species in the soil seed bank. These soil samples were placed in greenhouse trays and allowed to germinate for 28 days. At the completion of 28 days the weed seeds were extracted from the soil samples. After extraction the seeds were identified and counted under a microscope. The germination potential of pigweed seed was reduced when soil temperatures rose above 14°C. These results suggest that this weed was induced into secondary dormancy when field soil temperatures rose above 14°C. The relationship between common purslane germination and soil temperature was not as clear. Other parameters such as soil moisture and light may interact with soil temperature to regulate germination in common purslane. The percentage of common purslane in the seedbank capable of immediate germination, i.e., was nondormant, ranged from 0.1 to 33%. During the same period, the percentage of nondormant pigweed ranged from 0 to 48%. For most of the lettuce planting season pronamide controls the largest number of weeds. However, during the warm months when pigweed germinates, bensulide provides control of most weed species.

Introduction

Preemergence herbicides are by their nature preventative treatments applied to increase the likelihood that a crop can be produced successfully without losses due to weeds. The difficulty in using preemergence herbicides in an integrated weed management system is that one must apply these herbicides before the weeds germinate. Environmental conditions such as high soil temperature and moisture stress can reduce weed germination in newly planted fields. When a producer applies a preemergence herbicide, he has no way of knowing what caused the reduced germination; the herbicide or the environmental factors. Because there are no established models to predict weed germination in California vegetable crops, it is not possible for a grower to know when or which preemergence herbicide is needed. Growers do not know if the herbicide that they choose is the best choice to control the weed species that will be germinating at the time of lettuce planting.

Previous studies have demonstrated a relationship between temperature and the induction of secondary dormancy. Forcella et al. (1992, 1997) found that soil temperatures in the 16 to 20°C range induced secondary dormancy, i.e., reduced the germination rate, of giant foxtail and common lambsquarters. This raises the question: are there intervals during the long central coast lettuce planting season when most weeds are dormant? If most weed seed are dormant can lettuce be grown with reduced herbicide rates?

The objectives of this work were: 1) determine if seasonal seed dormancy occurs in weeds common to coastal California lettuce fields, and 2) investigate whether herbicide inputs can be reduced in late-summer planted lettuce.

Materials and methods

Field plots. Field plots 26 by 75 ft. were established in lettuce fields at Chualar, CA on 3-4-98, and at Salinas, CA on 4-2-98. Each study was arranged in a randomized complete block design with four replications. The lettuce crops were grown to maturity using cultural practices typical of the Salinas Valley. The Chualar plot was planted to radicchio in July 1998, and the crop was harvested in October of 1998. The Chualar site has been fallow from November 1998 through March 1999. The Salinas plot was replanted to lettuce August 1998, and harvested in November 1998. The Salinas site has been in barley cover crop from November 1998 until March 1999. Weed density counts were taken monthly at both sites at fixed locations within each plot, weather and field conditions permitting. Weed density counts were normalized relative to the month when the highest weed density for each species occurred, i.e., the month with the highest weed density for a 12 month period was 100% of possible density. The formula used in this calculation was: $N = (D/MD) * 100$, where N = the normalized weed density, D = the density of species A for any month and MD = the maximum density of species A for a 12 month period.

Soil samples. Twenty 2 by 2 inch soil cores per plot were taken in a W-shaped pattern as described in Forcella et al. (1992). The 20 cores from each plot were mixed together,

weighed and placed in 11 by 11 inch greenhouse trays and maintained in growth chambers set at constant 20°C day/night temperature or 25°C and 18°C day/night temperatures, respectively. The trays were watered regularly for 28 days. Weeds that emerged were identified, counted and removed on days 14 and 28, additionally the soil was stirred on day 14. Watering was discontinued on day 28 and the trays were allowed to dry for 7 days before bagging and storage at –20°C. Weed seeds were extracted from the soil as per Gross and Renner (1989). The seed were identified by weed species and counted under 10 to 20X magnification. Soil samples at the Chualar site were taken on 3-4-98, 4-15-98, 5-29-98, 7-10-98, 8-20-98, 9-28-98, 11-6-98, 12-18-98, 2-4-99 and 3-17-99, and at the Salinas site on 4-2-98, 5-18-98, 7-2-98, 8-13-98, 9-24-98, 11-5-98, 12-17-98, 1-29-99 and 3-12-99. Extractions have been completed for the 3-4-98, 4-15-98, 5-29-98, 7-10-98, 8-20-98, 9-28-98 and 11-6-98 samples taken at Chualar. Extractions for the Salinas site are currently in progress. Please note that this project has been selected for funding for 1999-2000, and it is expected that all samples previously and now being collected will be completed within the funding period.

Dormant percentage determination. The percentage of dormant seeds in the soil seed bank was determined by the equation $D = U / (U + N) * 100$, where D is the dormant percentage, U is the number of ungerminated viable seeds extracted from the soil, and N is equal to the number of seeds that germinated during 28 days in the greenhouse trays. Differences in the dormancy status of weed seeds at the 6 week sample intervals were detected by LSD's or 95% confidence intervals calculated using the SAS GLM procedure.

Weed germination and soil temperature. The relationship between germination temperature and germination in the soil trays was determined by the procedure described in Bradford (1990). A description of the methodology for the calculation of these terms can be seen in Appendix II.

Late-season weed control. Late-season studies were established near King City, CA on 7-29-98 and near San Ardo, CA on 8-5-98. Each plot was 13 by 25 ft. arranged in a randomized complete block with 4 replications per treatment. Treatments included were pronamide at 0.75, 1.0, 1.5 and 2.0 lb ai/A, bensulide at 5.0 lb ai/A and the untreated check. The herbicides were applied at 20 gallons per acre with a CO_2 backpack sprayer. Weed density ratings were taken on 8-21-98 at both sites. Mean differences were detected using LSD's.

Results

Dormant percentage growth chamber results. The percentage of dormant common purslane, i.e., common purslane that did not germinate within 28 days in a growth chamber, varied between 66.7 to 99.9% over the March to November sample period with the lowest dormancy percentage occurring in the 4-15-98 samples, and the highest percentage occurring in the 9-28-98 samples (Table 1). The percentage of dormant pigweed seed was lowest, 52%, in the 4.15.98 samples and increased steadily to 100% in the 8-20-98 and 9-28-98 samples.

Field weed density counts. Field density counts revealed that the warm-season weeds such as common purslane, hairy nightshade and pigweeds emerged at the highest densities during April through September (Table 2). Cool-season species such as shepherdspurse germinated all year with the highest densities occurring during December to April. Burning nettle also germinates all year with the highest densities occurring during April to August. Common groundsel germinated heavily between December and April, but also had a mid-summer germination peak in July.

Weed germination and soil temperature. The thermal time temperature threshold detected for the common purslane and pigweed populations were 13.8 and 14.0°C, respectively (Table 3). The r^2 of 0.87 for pigweed indicates a strong relationship between soil temperature and germination potential, which suggests that when soil temperatures rise above 14.0°C that pigweed species are more likely to be induced into secondary dormancy than at soil temperatures below 14.0°C. The r^2 of 0.60 for common purslane suggests that soil temperature is only one parameter that controls the induction of secondary dormancy in this species, and that other parameters such as light and moisture may also influence the germination of this species.

Late-season weed control. At the San Ardo site, 1.0 lb ai/A pronamide provided acceptable control of hairy nightshade and suppression of pigweed (Table 4). Prefar at 5.0 lb ai/A provided acceptable pigweed control but did not control hairy nightshade. Weed populations at King City were light, and no differences were detected between treatments.

Discussion

Dormant fraction. Results from the germination of soil seedbank samples in the growth chamber suggests that the dormancy status of common purslane and pigweed fluctuate by season and that the highest germination potential for either species occurred in April (Table 1). However, the germination of these species in the field indicates that germination of common purslane and pigweed peaks in July and August (Table 2). Germination requires both the potential to germinate and the proper germination conditions such as warm soil temperatures, but not warm enough to induce secondary dormancy. In other words, the conditions for maximum common purslane and pigweed emergence did not occur all year, but only during certain soil temperature conditions that persist for relatively short periods of time.

Weed germination in the field and herbicide choice. These results suggest that when 15 cm soil temperatures reach 16 to 24°C, reduced rates of pronamide and or combinations of pronamide plus bensulide may be used to provide satisfactory control of weeds such as common purslane, hairy nightshade and pigweed species. Shepherdspurse densities at the Chualar site were light after April 15 and remained low until late fall 1998 (Table 2). Therefore, management of shepherdspurse should not be a deciding factor in choosing an herbicide during the warmer months. When the emergence calendar (Table 2) is compared with weeds controlled by bensulide and pronamide (Cudney et al. 1996) one

can estimate when each herbicide would be most likely to provide the highest level of weed control (Table 5). Based on the weed emergence data, pronamide appears to control the greatest number of weed species present at high densities during the December to May planting season. Bensulide herbicide is probably a good choice during the July and August period when pigweed is most common, because bensulide is more active on pigweeds than pronamide.

Late-season weed management. Low weed pressures at sites such as King City suggest that at some locations weed densities emerging in summer-planted lettuce may be so low that herbicide treatments are not necessary. Low-rate herbicide treatments may work well for summer-planted lettuce at sites where weeds such as hairy nightshade and shepherdspurse predominate. Field sites infested with common purslane will require special attention during the warm months since that species germinates readily at high soil temperatures.

Outreach. One field day was hosted by the PI on 8-4-98 and the some of the work described above was presented to about 20 pest control advisors and Cooperative Extension personnel. These data were presented in a seminar at the UC Davis, Department of Vegetable Crops on 10-27-98. Attendance was approximately 40 UCD faculty and students. These data were presented during the poster session at the California Weed Science Society meeting in Anaheim, CA on January 11 to 13, 1999. Attendance was approximately 650 pest control advisors and industry personnel. An oral presentation of the results of this research was made at the Weed Science Society of America annual meeting February 7 to 10, 1999 in San Diego, CA. Attendance was approximately 700 public and private sector weed scientists. Acknowledgment of the sponsorship of the California Department of Regulation was given during each of these presentations.

Summary and Conclusions

This study was conducted to: 1. determine if there were seasonal variations in weed emergence in the Salinas Valley, and 2. determine whether weeds in late-planted lettuce could be managed with reduced rates of herbicide inputs.
We have determined that there are seasonal fluctuations in weed emergence and have determined that there are seasonal variations in the potential for weed seeds to germinate. The practical application of this in California lettuce production is that there may be particular months of the year when it is advantageous to use bensulide or pronamide based on seasonal changes in weed spectrum. There may also be periods during the year such as late summer, when it is possible to reduce or even eliminate the use of an herbicide.

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List of publications produced

Crabb, C.B., and S.A. Fennimore. 1999. The germination profile of selected Salinas Valley Weeds. Proceedings of the California Weed Science Society (in press).

Fennimore, S.A., and C.B. Crabb. 1999. Seasonal weed emergence in California vegetable fields. Weed Science Society of America Abstracts 39:141.

Appendix I. Tables 1 to 5.

Table 1.   The percentage of dormant common purslane and pigweed seed in the soil seedbank at Chualar, CA on seven sample dates. To estimate the number of nondormant seed (N) the soil samples were allowed to germinate for 28 days. After 28 days the number of ungerminated seed (U) was determined by extracting the seed from the soil and counting the viable seeds remaining. The dormant percentage (D) was calculated by: $D=U/(U+N)*100$.

| | Dormant percentage | |
Sample date	Common purslane	Pigweed spp. [1]
3-4-98	88.4 AB	79.3 B
4-15-98	66.7 C	52.0 C
5-29-98	88.6 B	90.0 AB
7-9-98	74.0 BC	95.0 A
8-20-98	79.9 BC	100.0 A
9-28-98	99.9 A	100.0 A
11-6-98	95.9 A	97.6 A
LSD (0.05)	16.9	NA

[1] Mean differences were determined using 95% confidence intervals.

Table 2. Salinas Valley weed germination as a percentage of the month with the maximum germination. Weed counts were taken monthly from March of 1998 to February 1999 at two Salinas Valley sites. Weed emergence counts were normalized based on the month with maximum emergence, i.e., the month with maximum weed emergence densities for each species was 100%. [1]

Species	March	April	May	June	July	August	September	October	November	December	January	February
Burning nettle	6.6	62.3	100.0	42.3	12.1	97.2	24.3	7.8	28.1	27.6	28.3	10.8
Common groundsel	53.9	96.2	30.8	3.9	100.0	7.7	26.9	7.7	NA	88.5	NA	92.3
Common purslane	0.1	6.0	2.3	9.2	100.0	41.7	8.2	2.8	NA	3.7	NA	0.5
Hairy nightshade	0	0	58.6	10.2	8.6	NA	100.0	0.6	0	NA	NA	0
Pigweed spp.	0	86.8	3.8	22.6	100.0	35.6	9.4	15.1	NA	0	NA	0
Shepherdspurse	68.6	78.0	4.0	8.1	22.8	1.3	13.4	5.4	NA	100.0	NA	94.1

[1] NA – no data available for this species in the month indicated.

Table 3. Parameters of temperature-induced germination responses that characterize field populations of common purslane and pigweeds.

Species	$TT_b(50)$ [°C]	r^2
Common purslane	13.8	0.60
Pigweed spp.	14.0	0.87

Table 4. The number of weeds present per 0.44 m^2 of plant bed at the San Ardo site on 8-21-98 in each herbicide treatment.

Herbicide	Rate lb ai/A	Redroot pigweed	Hairy nightshade
pronamide	0.75	4.9 B	2.6 A
pronamide	1.0	3.3 AB	1.5 A
pronamide	1.5	4.6 B	0.8 A
pronamide	2.0	2.5 AB	0.4 A
bensulide	5.0	1.3 A	6.3 B
untreated	--	10.8 C	8.0 B
LSD (0.05)		2.9	3.1

Table 5. A weed germination calendar for Salinas Valley lettuce fields, and likely weed control, or non-control, results by month when bensulide or pronamide are used as the base preemergence herbicides. [1,2]

Herbicide efficacy	January	February	March	April	May	June	July	August	September	October	November	December
Weeds controlled by bensulide	nettle	nettle		nettle pigweed	nettle	nettle pigweed	purslane pigweed	nettle purslane pigweed	nettle		nettle	nettle
Weeds not controlled by bensulide		groundsel shepherds.	groundsel shepherds.	groundsel shepherds.	groundsel nightshade	shepherds.	groundsel		groundsel nightshade			groundsel shepherds.
Weeds controlled by pronamide	nettle	nettle shepherds.	shepherds.	nettle shepherds.	nettle nightshade	nettle	purslane shepherds.	nettle purslane	nettle nightshade		nettle	nettle shepherds.
Weeds not controlled by pronamide		groundsel	groundsel	groundsel pigweed	groundsel	pigweed	groundsel pigweed	pigweed	groundsel			groundsel

[1] Guide to weed species - nettle: burning nettle, nightshade: hairy nightshade, pigweed: *Amaranthus* spp., purslane: common purslane, shepherds: shepherdspurse

[2] Weed species were only listed as a potential problem if they were present above 20% of maximum annual weed density.

Appendix II. Methods to establish the relationship between germination potential and soil temperature.

Responses of weed seeds to plant hormones and temperature have been quantified by population-based threshold models (Bradford 1990, Oryokot et al. 1997). The determination of threshold values for a seed population allows the prediction of the germination rate of that population after exposure to a given temperature. The threshold model assumes that the germination rate of a seed population is proportional to the difference between the temperature and the temperature threshold value of the seed population. Germination response can be expressed as:

$$\theta_{TT} = \{log[d] - log[TT_b(g)]\}tg$$

Where θ_{TT} is the thermal time constant in days, $log[d]$ is the log time in days, $[TT_b(g)]$ is the base threshold temperature which results in germination of percentage g, σ_{TTb} is the standard deviation of TT_b and tg is time to germination of percentage g. These parameters then allow the prediction of germination time-courses with the following equation:

$$probit\ (g) = \{log[d] - (\theta_{TT}/tg) - log[TT_b(50)]\}/\sigma_{TTb}$$

where probit (g) is the transformation of a cumulative percentage in a standard normal cumulative distribution to corresponding standard deviation units.

The data were analyzed as described in Bradford (1990). Germination percentages were transformed into germination probits by the NORMSINV (inverse of the standard normal distribution) function with an Excel spreadsheet. The Excel statistical regression package was used to regress the germination probits verses the log of the TT_b base temperature as described by Bradford (1990).